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# Problem Based Learning and Deep Learning Approach Effects on Student Learning Outcomes

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## Abstract

This study aims to determine the effect of Problem Based Learning (PBL) model assisted by PhET Simulation with Deep Learning approach on student learning outcomes on dynamic fluid topic. The research used a quantitative approach with a quasi-experimental design. The subjects consisted of two XI classes in one of the randomly selected high schools in Semarang. The experimental class used the PBL model combined with PhET simulation to fill in the Learner Worksheet (LKPD) related to the discharge and continuity equations, while the control class did not use PhET and did not fill in the LKPD. Both classes were then given a learning outcome test. The results of the analysis using the Mann-Whitney test showed a significant difference between the learning outcomes of the two classes ($U = .000$, $Z = -5.737$, $p < 0.001$), with the experimental class scoring higher ($M = 80$) than the control class ($M = 19$). These findings show that the PBL model assisted by PhET Simulation and a deep learning approach improved student learning outcomes. The conclusion of this study is that the application of PBL model assisted by PhET Simulation and Deep Learning approach effectively improves student learning outcomes on dynamic fluid topic.

## How to Cite

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## INTRODUCTION

Physics as one of the science subjects has conceptual and abstract characteristics, which require students to have higher order thinking skills (Rahimi et al., 2022). One topic that is often a challenge for students is dynamic fluid, which contains concepts such as Bernoulli's law, the principle of continuity, and viscosity. This topic requires a deep understanding and the ability to connect concepts with real phenomena. However, in practice, many students have difficulty understanding this topic because learning is still oriented towards conventional approaches with minimal interaction and exploration of concepts (Liana et al., 2023).

The Problem-Based Learning (PBL) learning model has been widely researched as one of the effective innovative approaches to improve critical thinking and problem solving skills. (Zulva et al., 2024) stated that PBL consistently shows a positive impact on student learning outcomes in physics learning. In fact, the application of the PBL model assisted by PhET simulation is proven to significantly improve students' problem solving skills in the context of physics learning (Liana et al., 2023). PhET simulations are known to provide interactive visual representations, helping students understand abstract concepts more concretely (Haetami et al., 2023). Meaningful learning can be achieved when students are actively engaged and understand concepts in depth, including through digital simulation-based learning media such as PhET (George-Williams et al., 2019). The use of PhET simulations has a positive impact on students' attitudes and understanding in basic chemistry learning, and can also be applied in physics (Salame & Makki, 2021). Interactive simulation-based learning activities such as PhET can improve student performance and learning experiences in abstract topics such as electromagnetism (Batuyong & Antonio, 2018). PhET simulations have also been shown to be effective in improving students' scientific process skills and conceptual understanding in physics learning (Haryadi & Pujiastuti, 2020). In addition, (Utami et al., 2023) emphasized the importance of decision making as part of problem solving skills that must be developed through higher order thinking activities in physics learning.

Meanwhile, learning approaches that encourage deep cognitive engagement such as deep learning are also increasingly relevant in 21$^{st}$ century education. 21$^{st}$ century learning demands meaningful, differentiated and inclusive learning experiences in accordance with students' potential, as stated by (S. Wahyuni & Khoiri, 2023) in the idea of transforming learning through differentiation. Similarly, research by (Ding & Yu, 2024) confirmed that when students are actively engaged in game or simulation-based learning, their science learning outcomes improve significantly. (Petersen et al., 2023) also found that collaborative generative learning activities in an interactive virtual environment can improve student engagement and learning outcomes. These findings reinforce the urgency of using interactive media and participatory approaches in science learning, including physics.

Continuous assessment that emphasizes self-reflection can transform learning from a mere collection of grades to a more meaningful learning process (Rodríguez Rincón et al., 2024). Digital game design in the classroom can support meaningful learning experiences by combining engaging gameplay and clear learning objectives (Clark et al., 2023). The development of learning media based on the joyful learning model can increase student motivation and involvement in the learning process (Rahma & Asih, 2024). The deep learning approach through meaningful, mindful, and joyful learning contributes significantly to improving the effectiveness of the learning process (Feriyanto & Anjariyah, 2024). Joyful learning can create a learning environment that supports students' emotional and cognitive engagement (Bhakti et al., 2019). Joyful learning strategies that incorporate elements of humor can increase student interest and achievement, including in language and science learning (W. Wahyuni & Naim, 2019). Collaboration among students is an effective strategy for creating meaningful learning in the teaching and learning process (Vera et al., 2020). Digital-based mindfulness training supports modern learning processes that are adaptive and technologically integrated (Mrazek et al., 2019).

Although various studies have examined the effectiveness of each approach separately such as PBL (Liana et al., 2023; Zulva et al., 2024), PhET simulation (Haetami et al., 2023), and interactive technology approach (Ding & Yu, 2024; Jiang & Jiang, 2024; Petersen et al., 2023). Very few studies have tried to combine the three in one learning design. In fact, the integration of the three in dynamic fluid specifically has never been studied in depth. This research presents a novelty by integrating Problem-Based Learning model, PhET Simulation media, and deep learning approach in one learning framework for dynamic fluid topic. This approach not only helps students in understanding concepts through interactive simulation and problem solving, but also encourages them to build meaning deeply and reflectively. This combination has not been widely discussed in previous studies, so it is expected to be able to fill the gap in the literature and become a new contribution in the development of 21st century physics learning. The urgency of this research is based on the need to improve 21st-century learning practices, particularly in physics education, by developing students' competencies in critical thinking, problem solving, and collaboration through technology-based methods.

Previous studies have shown that PBL has been extensively researched and proven to improve critical thinking skills, problem solving, and student engagement in physics learning. In addition, the use of PhET simulations has also been proven effective in helping students understand concepts through interactive visual representations. Meanwhile, the deep learning approach is beginning to be recognized as a strategy that can encourage more meaningful, reflective, and deep understanding-oriented learning. However, these studies generally examine the three approaches separately, and studies that integrate two approaches at once are still relatively rare. To date, there has been no research that explicitly integrates PBL, PhET simulations, and the deep learning approach in a single learning design to improve physics learning outcomes, especially on the topic of fluid dynamics. This gap is the basis for the importance of this research.

## METHOD

This research used a quantitative approach (Azhari et al., 2023) with a quasi-experimental design, the learning method used is Problem Based Learning which emphasizes solving real problems by students actively (Zulva et al., 2024). The research method used in this study differs from previous studies. Most previous studies examining PBL, PhET, or deep learning approaches used a pretest–posttest design. However, this study used a posttest-only control group design, because the focus of measurement was directed at the effectiveness of the final learning outcomes after the treatment was given without comparing them to the initial abilities. This design was chosen to avoid the testing effect and initial intervention bias in the experimental group. This study aims to determine the effect of Problem Based Learning (PBL) model assisted by PhET Simulation and deep learning approach on student learning outcomes on dynamic fluid topic. The research was conducted in one of the high schools in Semarang in the even semester of the 2024/2025 academic year. The research subjects consisted of two XI classes selected by random sampling, each as an experimental class and a control class. The experimental class applied PBL model assisted by PhET Simulation combined with deep learning approach, while the control class used conventional learning with PBL model without the help of PhET Simulation combined with deep learning approach. The control class in this study did not receive treatment in the form of PBL integration, PhET Simulation, and deep learning approaches. Learning was conducted using conventional methods in the form of structured lectures, concept explanations, and exercises without the use of simulations or problem-solving scenarios. The teacher who taught the control class were the same as those who taught the experimental class to maintain teaching competency equality. In addition, the allocation of time, material, and learning environment were made equivalent so that the final results obtained could reflect the difference in treatment, not the difference in learning conditions. The researchers also ensured that students in the control class did not access the material or simulations given to the experimental class during the study to avoid treatment contamination.

The deep learning approach in learning is integrated through phenomenon observation activities, simulation-based modeling, concept reflection, and contextual application (Arias Chao et al., 2022; Piloto et al., 2022). Learning media developed using joyful learning model with interactive and fun activities to increase student engagement (Rahma & Asih, 2024). The deep learning approach is applied by emphasizing meaningful, mindful, and joyful learning aspects to support the deep learning process (Feriyanto & Anjariyah, 2024). The stages of the Problem Based Learning (PBL) Model Integrated with the Deep Learning Approach are shown in Figure 1.

The research instrument used was a multilevel multiple choice test that had been validated by experts. The learning outcome test instruments in this study underwent expert judgment validation to ensure that the content of the instruments was appropriate for the learning objectives. The validation process was carried out by three experts consisting of physics education lecturers and high school physics teachers. The assessment covered the suitability of the questions with the learning indicators, clarity of language, construction of questions, and the accuracy of the material context with the topic of fluid dynamics. Based on the results of the assessment and revisions provided by the experts, the instrument was declared suitable for use as a data collection tool. Reliability testing was not conducted because the instrument did not undergo a preliminary trial phase before being used in the study.

The data obtained were analyzed using the Mann-Whitney nonparametric statistical test because the data were not normally distributed, which aims to compare differences in learning outcomes between the experimental group and the control group (Azhari et al., 2023). The use of PhET simulation media in physics learning aims to strengthen conceptual understanding and facilitate visualization of fluid dynamics, as shown in previous studies that this media can increase student motivation and interest in learning (Rahayu & Wibowo, 2023; Yaqutu Burhani et al., 2022). The application of PBL is also believed to be able to encourage student involvement in learning activities that are meaningful and oriented towards solving real problems, as well as improving higher order thinking skills (Saldo & Walag, 2020).

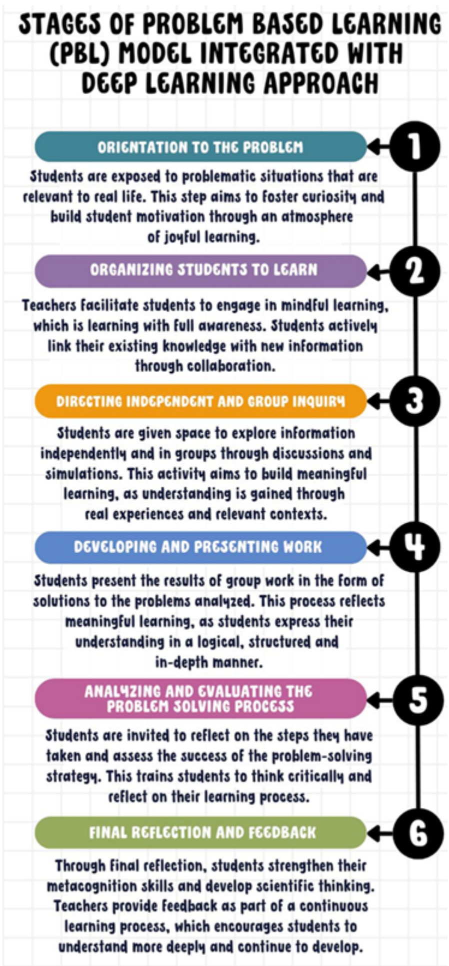


**Figure 1.** Stages of Problem Based Learning (PBL) Model Integrated With Deep Learning Approach

## RESULT AND DISCUSSION

This study aims to determine the effect of Problem Based Learning (PBL) model assisted by PhET Simulation media with Deep Learning approach on student learning outcomes on dynamic fluid topic. Learning outcomes data were analyzed using the Mann-Whitney U test because the data distribution did not meet normality. The statistical test results in Table 1 show the value of Asymp. Sig. (2-tailed) value of 9.609E-9 or $p < 0.001$, which indicates a significant difference between the experimental and control classes. Thus, the application of PBL assisted by PhET Simulation with a Deep Learning approach has a real influence on student learning outcomes.

**Table 1.** Statistical Test Results

| Test Statistics | Learning Outcomes |
|---|---|
| Mann-Whitney U | .000 |
| Wilcoxon W | 210.000 |
| Z | -5.737 |
| Asymp. Sig. (2-tailed) | .000 |

The difference in learning outcomes is also evident from the average score of each class shown in Figure 2, which is 80 for the experimental class and 19 for the control class, with a significant difference of 61 points. This finding supports the results of previous studies which state that problem-based learning and the use of interactive simulation media effectively improve concept understanding and student engagement (Haetami et al., 2023; Liana et al., 2023).

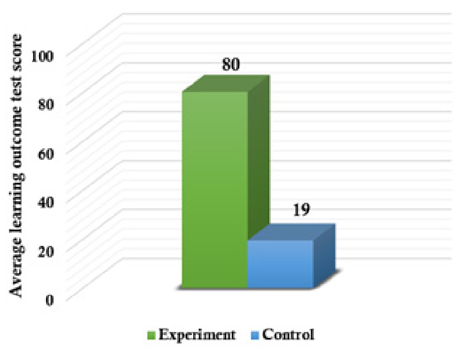


**Figure 2.** Graph of the average value of the class learning outcome test

The findings presented in Figure 2 show significant differences in learning outcomes between the experimental class and the control class. To further understand the causes of these differences, the results of observations during the learning process were analyzed. Based on observations, the learning process in both classes showed clear differences in terms of interaction, student engagement, use of media, and learning activities. In the experimental class, learning was carried out using the Problem-Based Learning (PBL) model combined with PhET Simulation and the Deep Learning approach. Students were active in identifying problems, discussing in groups, and exploring simulations by changing variables such as flow rate, pressure, and cross-sectional area to see the relationship between concepts directly. This learning environment encouraged curiosity, collaboration, and meaningful cognitive engagement. Interactive simulations and problem-solving activities helped students visualize abstract concepts and build deeper understanding through reasoning and evidence. Meanwhile, learning in the control class took place conventionally through lectures and exercises without the use of PhET Simulation or investigative activities. Students tended to be passive and dependent on the teacher's explanations, with limited opportunities for discussion or further exploration of concepts. Learning became procedural, focusing on memorizing formulas rather than understanding concepts. The lack of interaction and media support also resulted in low motivation and cognitive engagement among students.

The differences in learning approaches, classroom interaction, and student engagement logically explain why there were significant differences in learning outcomes between the two classes based on statistical tests. Thus, the application of PBL combined with interactive simulations and a deep learning approach proved to be more effective than conventional learning. The Deep Learning approach in learning process provides deeper understanding of physics concepts and adaptability to complex learning models (Jiang & Jiang, 2024; Piloto et al., 2022). In addition, the use of interactive and realistic PhET simulations facilitates virtual exploration of dynamic fluid concepts, thus strengthening students' learning process constructively and critically (Rahayu & Wibowo, 2023; Burhani et al., 2022).

This learning model also supports 21st century skills, such as creativity, collaboration, and critical thinking needed in modern science learning (Ananiadou & Claro, 2009; Supena et al., 2021). By combining PBL, PhET Simulation, and Deep Learning, learning becomes more meaningful and stimulates students' active engagement in understanding dynamic fluid physics phenomena. Meaningful learning in mathematics and science occurs when students are able to relate the concepts they learn to real-life contexts (Polman et al., 2021). Students' learning styles and motivation greatly influence their success in achieving meaningful learning (Zubaedi et al., 2021). The use of PhET simulations can simultaneously improve students' conceptual understanding and motivation to learn in science education (Gani et al., 2020). Using technology to teach mindfulness in the classroom improves teachers' psychological well-being and their confidence in teaching (Klusmann et al., 2023). Mindfulness-based learning program shows strength in improving students' emotional well-being during the learning process (Do & Giang, 2024). Informal mindfulness teaching is proven to help students' psychological development, particularly in managing stress and improving learning focus (Mettler et al., 2024). The mindfulness approach in education can enhance students' creativity and deep thinking skills (Henriksen et al., 2020). Mindful learning helps students focus better and engage emotionally and cognitively in the learning process (Ashari & Ghasemzadeh, 2019). Educational strategies that integrate mindfulness support the development of self-awareness and improve the quality of learning (Weare, 2019). Personalized learning helps students achieve more meaningful learning outcomes that are tailored to their individual needs (Abedi et al., 2019). Teachers who are empowered through reflection and classroom action research have great potential to enhance meaningful learning experiences for students (Barkhuizen et al., 2018).

Overall, this research shows that the integration of simulation technology and a problem-based learning approach with a touch of Deep Learning has a significant impact on improving student learning outcomes, while preparing them for the challenges of 21st century learning (Ding & Yu, 2024; Rahimi et al., 2022).

**Table 2.** Normality Test Results

| **Class** | **Tests of Normality** | | | | | |
|---|---|---|---|---|---|---|
| | Kolmogorov-Smirnova | | | Shapiro-Wilk | | |
| | Statistic | df | Sig. | Statistic | df | Sig. |
| Experiment class | .168 | 25 | .067 | .923 | 25 | .061 |
| Control class | .230 | 20 | .007 | .917 | 20 | .088 |

Based on the normality test results of the experimental and control class student learning outcomes data using the Kolmogorov-Smirnov and Shapiro-Wilk tests shown in Table 2, it is known that the control class data is not normally distributed ($p = 0.007 < 0.05$), while the experimental class data is normally distributed ($p = 0.067 > 0.05$). Therefore, the non-parametric Mann-Whitney U test was used to test the difference in learning outcomes between the two classes. The Mann-Whitney U test results showed significant differences between the learning outcomes of experimental class students who applied the Problem Based Learning (PBL) model assisted by PhET media with a Deep Learning approach, and the control class who used conventional learning. The results of the analysis showed that students' decision-making skills improved significantly after the implementation of the problem-based learning model (Utami et al., 2023). The Problem-Based Learning model has also been proven effective in improving student learning outcomes, especially when packaged in digital form or e-modules (Jaenudin & Murwaningsih, 2017).

This finding is in line with previous research which shows that the application of interactive simulation-based PBL can improve students' conceptual understanding and learning outcomes in physics topic (Haetami et al., 2023; Liana et al., 2023). The use of PhET Simulation in physics learning allows students to explore concepts independently and collaboratively (Liu et al., 2021). PhET media provides a visual and interactive representation of the abstract concept of dynamic fluid, making it easier for students to build a deep understanding (Liana et al., 2023).

The Problem Based Learning (PBL) model has been proven to improve student learning outcomes because this approach encourages active engagement through investigation, discussion, and problem solving based on real world contexts, so that students not only receive information but also construct knowledge through meaningful learning experiences. Through these activities, students are trained to develop higher order thinking skills such as analysis, evaluation, and synthesis, which ultimately lead to improved conceptual understanding, material retention, and the ability to transfer knowledge to new situations. The use of PhET Simulation media also strengthens the learning process because it provides interactive visualizations of abstract concepts, allowing students to manipulate variables directly, get instant feedback, and connect theory with the physics phenomena they observe virtually.

Thus, PhET helps reduce misunderstandings and strengthen conceptual understanding, especially in subjects such as fluid dynamics, which are abstract and difficult to understand through conventional learning. The deep learning approach further strengthens the implementation of PBL because both are based on the principles of constructivism and meaningful learning, which require students to not only memorize but also reflect on, integrate, and apply concepts in real life contexts. In practice, deep learning makes the PBL process more meaningful because students are encouraged to connect new knowledge with prior knowledge, collaborate, test ideas, and reflect on their thinking processes. The collaboration of these three elements, namely PBL, PhET simulations, and the deep learning approach, can create an active, reflective, and student centered learning experience, thereby contributing significantly to improving conceptual understanding and learning outcomes in physics.

The application of PBL based on deep learning encourages students to connect prior knowledge, construct meaning, and present their understanding in group discussions (Roy et al., 2023; Zhao et al., 2023). The Deep Learning approach also plays an important role in improving learning outcomes as it focuses on meaningful conceptual understanding, the ability to connect between concepts, and the application of knowledge in a new context (Entwistle & McCune, 2004; Jiang & Jiang, 2024). This is in line with the study (Piloto et al., 2022; Shi et al., 2022) which shows that the Deep Learning approach improves cognitive engagement and quality of understanding in science and physics-based learning. By implementing reflection-based continuous assessment, students experience increased understanding of concepts in greater depth (Rodríguez Rincón et al., 2024). Deep learning facilitates the process of elaboration, integration of knowledge, and transfer of concepts into real contexts (Shi et al., 2022).

Furthermore, the integration of technology-based learning and PBL approach also supports the development of 21st century skills, such as critical thinking, problem solving, and collaboration (Ananiadou & Claro, 2009; Supena et al., 2021). Student response to the use of joyful learning media is very positive, as evidenced by increased motivation and active participation in learning (Donasari et al., 2023). Learning activities that emphasize real problem solving, independent exploration, and teamwork encourage students to be actively and reflectively involved in the learning process (Saldo & Walag, 2020).

An enjoyable learning experience encourages students to be more active and interested in subjects such as mathematics and physics (Yabo, 2020). The Problem Based Learning (PBL) model is proven to be able to increase student motivation and learning outcomes because it encourages them to be more active in solving problems related to everyday life (Gulo, 2022). Previous research also shows that the application of PBL has a significant positive effect on student learning outcomes, because this model emphasizes active involvement in the process of critical thinking and problem solving (Djonomiarjo, 2020).

Joyful learning is proven to significantly increase students' learning motivation (Sigit Gesang Permana et al., 2022). The joyful learning approach can shape students' positive attitudes toward science subjects from an early age (Anggoro et al., 2017). Joyful learning can also be applied to build student motivation during learning with a problem-based approach (Widyawulandari & Indriayu, 2019). Mindfulness instruction can improve EEG dynamics and higher order thinking skills (HOTS), thus positively impacting learning effectiveness (Ghanizadeh et al., 2024). Deep learning approaches develop through challenging learning experiences, such as solving contextual problems in PBL (Asikainen & Gijbels, 2017). Deep learning informed by principles of physics, including in the context of fluid simulation, has great potential to improve students' conceptual understanding (Eivazi et al., 2024). The joy of learning is key to supporting emotional engagement and strengthening students' deep thinking processes (Cronqvist, 2021). Thus, the combination of PBL, PhET media, and Deep Learning approach significantly contributes to the improvement of student learning outcomes on dynamic fluid topic. This indicates that technology-based learning innovations and active learning strategies need to be continuously developed to improve the quality of physics education in the modern era. Integration of Problem Based Learning with PhET media and deep learning approach proved effective in increasing students' interest in learning, collaboration skills, and understanding of physics concepts (Pimdee et al., 2024).

Based on the results of the study, these findings indicate that physics education today needs to transform from conventional methods to technology based learning, problem solving, and deep understanding. The application of Problem Based Learning combined with PhET simulation media and the Deep Learning approach has been proven to significantly improve learning outcomes compared to traditional learning. This confirms that students find it easier to understand abstract physics concepts when given the opportunity to explore, visualize phenomena, discuss, and actively construct meaning. In addition, this learning model also supports the development of 21st-century skills such as critical thinking, collaboration, and problem solving skills. Thus, today's education needs to integrate interactive technology, active learning strategies, and joyful and mindful learning approaches so that the learning process not only improves conceptual understanding but also student motivation, participation, and meaningful learning.

## CONCLUSION

Based on the results of data analysis, it can be concluded that the application of the Problem Based Learning model assisted by PhET Simulation media with a Deep Learning approach has a significant effect on student learning outcomes on dynamic fluid topic. This is evidenced by the significant difference in learning outcomes between experimental and control class students based on the Mann-Whitney U test with a p value $<0.001$. Thus, the use of innovative learning models is able to improve concept understanding and achievement of student learning outcomes more effectively than conventional learning methods. Therefore, it is recommended for teachers to implement the Problem Based Learning model with the support of PhET simulation media and Deep Learning approach to improve learning outcomes and student motivation, especially in conceptual and applicable topic. In addition, future researchers are expected to develop research with a wider scope, both in terms of the number of samples and the variety of subject matter.

This study has several limitations, namely a limited sample size of two classes in one school, a relatively short research duration, and an instrument that only measures cognitive learning outcomes without assessing other aspects such as motivation, interest in learning, and collaboration skills. In addition, the use of technology such as PhET Simulation requires different adaptations for each student, and some external variables cannot be fully controlled. Therefore, further research is recommended to involve a broader and more diverse sample, use a longer duration, involve additional instruments such as motivation questionnaires or observations, and develop the integration of technology and other learning approaches so that the results obtained are more comprehensive and can be generalized.

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